UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
WASHINGTON, D. C.
H. H. BENNETT, CHIEF

ADVANCE REPORT

on the

SEDIMENTATION SURVEY OF LAKE ELDORADO

ELDORADO, KANSAS

April 20 to May 8, 1937

by

Victor H. Jones

Sedimentation Studies
Division of Research
SCS-SS-25
July 1938

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INTRODUCTION

The sedimentation survey of Lake Eldorado was made during the period April 20 to May 8, 1937, by the Section of Sedimentation Studies, Division of Research, Soil Conservation Service, in cooperation with the Kansas Agricultural Experiment Station. The survey party consisted of Louis M. Seavy, chief of party, Arnold B. Taylor, Earl H. Moser, Jr., Harold R. New, Jonas Spitler, and Duncan T. Axford. Preliminary data were secured and arrangements for the survey made by F. F. Barnes. Studies of the lake sediments and an inspection of the drainage area were made by Victor H. Jones, assisted by the field party. F. L. Duley, field representative of the Research Division, aided in arranging cooperative agreements and coordinating the field program.

Moisture determinations and mechanical analyses of sediment samples were made under the direction of Professor W. H. Metzger in the soils laboratories of Kansas State College at Manhattan. An original map of the reservoir basin and blueprints of the dam were supplied by Black and Veatch, consulting engineers, Kansas City, Missouri.

The cooperation and assistance of the Eldorado municipal officials, especially H. E. McMillen, city engineer, and Frank L. Seymour, city manager, greatly facilitated the sedimentation survey of Lake Eldorado. The city furnished maps of the drainage area and information on the history and cost of the reservoir.

George S. Knapp, chief engineer of the Division of Water Resources, Kansas State Board of Agriculture, supplied information on a large number of lakes in Kansas, which was of great assistance in selecting reservoirs for detailed study.

GENERAL INFORMATION

Location (fig. 1):

State: Kansas.

County: Butler. Secs. 15, 16, 17, 20, 21, and 22, T. 25 S., R. 6 E.

Distance and direction from nearest city: The dam is 4.7 miles northeast of the courthouse square in Eldorado.

Drainage and backwater: Satchel Creek, which flows about one mile west from the dam to join the Walnut River, a tributary of the Arkansas River.

Ownership: City of Eldorado.

Purpose: Municipal and industrial water supply and recreation.

Description of dam.

Lake Eldorado is impounded by an earthen dam 1,800 feet long, 40 feet in maximum height above the stream bed, and 12 feet wide at the top. The top of the dam has an average elevation of 1,308 feet above mean sea level and is 8 feet above spillway crest level. The upstream amd downstream faces of the dam have slopes of 3:1 and 2:1 respectively, and the upstream face is covered with concrete. A clay core wall and Wakefield sheet piling extending to bedrock provide watertightness for the earth embankment.

The concrete spillway at the north end of the dam has a crest elevation of 1,300 feet and a height of 32 feet above the stream bed. It is arc-shaped and has a chord length of 360 feet and a crest length of approximately 400 feet. The intake well is in the channel 160 feet upstream from the center line of the dam.

The total original cost of the development was covered by a bond issue of $439,471.

Date of completion of dam: April 16, 1923. At the time of the sedimentation survey the lake was 9 years old.

Length of lake: 2.65 miles from the dam to the head of backwater, of which 0.76 mile is a narrow ponded channel.

Area of lake at spillway stage: 362 acres. There had been no reduction by sedimentation up to the date of survey.

Figure 1

MAP SHOWING LOCATION OF LAKE ELDORADO

L-2146

Storage capacity to spillway level:

	Acre-feet	
Original	3,213	(1,046,956,050 gals.)
At date of survey	3,082	(1,004,269,700 gals.)
Reduction by sedimentation.....	131	(42,686,350 gals.)

General character of reservoir basin.

The lake occupies a straight, elongated basin that extends northeastward from the dam (fig. 2, following p. 14). The lake width increases irregularly upstream from about 1,900 feet at range R1 near the dam to a maximum of nearly 2,500 feet at range R6. Above this range the basin tapers more or less gradually to an abrupt constriction less than 160 feet wide at the head of the main lake in segment 14. Thence to the head of backwater the basin consists of a tortuous ponded channel ranging from 100 to 500 feet in width and containing several small islands.

The shore line is made moderately irregular by about six small bays on each side of the main body of the lake. The largest of these bays, extending northward from range ends R9R and R10R, has a length of 800 feet and a width of 500 feet at its mouth.

Cross sections of the basin are distinctly asymmetrical on ranges R2 to R13, inclusive. The submerged valley sides have an average inclination of about 3 percent all along the north shore and 8 percent along the south shore. The submerged flood plain is nearly 1,500 feet wide between the dam and range R11. Its surface has relatively few irregularities other than the stream channel, which has an average width of about 100 feet and a depth of 12 feet.

The channel follows a tortuous course for 2.9 miles through the reservoir and has a gradient of 11 feet per mile from the head of backwater to range R1.

Area of drainage basin: 33 square miles, as determined by planimeter measurement of a map prepared by Black and Veatch,[1] consulting engineers.

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[1] Black and Veatch, General map, water-supply investigations, Eldorado, Kansas. October 1925.

General character of drainage basin.

Geology.--The area tributary to Lake Eldorado (fig. 3) lies within the Flint Hills section of the Central Lowland province. The bedrock at and near the surface in the drainage area consists of limestones and shales of Permian age, as shown in the following generalized section, compiled from field notes made during the survey and from other sources, especially publications of the Kansas Geological Survey.[2]

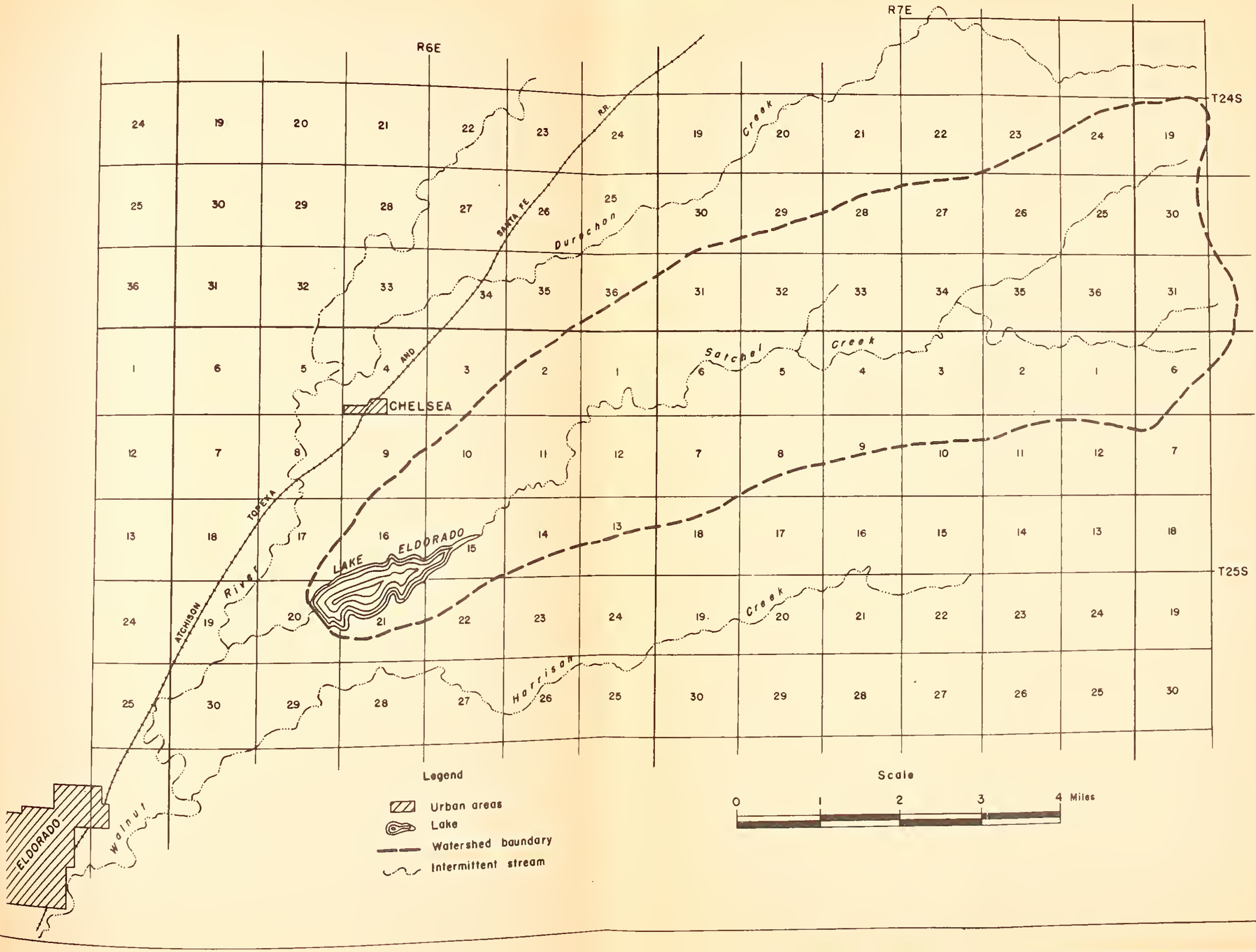
Generalized section of strata in the Lake Eldorado drainage basin

	Thickness in feet
Quaternary:	
Clay, silt, limestone gravel; on valley bottoms.....	0-6
Paleozoic:	
Permian:	
Marion formation:	
Limestone and shale; occurs only as remnants on the uplands.....	0-12
Chase formation:	
Winfield member--	
Limestone; occurs only on upland near the reservoir.....	0-6
Doyle member--	
Shale, greenish, and limestone; on slopes and uplands.....	50-70
Fort Riley member--	
Limestone, gray, fossiliferous; occurs along the south lake shore.....	40
Florence member--	
Cherty limestone; occurs in stream banks below the dam.....	20
Pennsylvanian:	
Wabaunsee formation:	
Limestone and shale; not exposed within the watershed.....	--

[2]Fath, A. E. Geology of the Eldorado oil and gas field, Butler County, Kansas. Kans. Geol. Survey Bull. 7, 1921.
Moore, R. C., Landes, K. K., and others. Geologic map of Kansas. Scale 1/500,000, 1937.

Figure 3

MAP OF LAKE ELDORADO DRAINAGE BASIN AND ADJACENT AREA
BUTLER COUNTY, KANSAS



R-1666

Limestones and shales are the only important rock types in the drainage area. The fine-textured silty and clayey residual soils derived from these rocks are the principal sources of the reservoir sediment. Some gravel is produced during the weathering and transportation of fragments of this limestone, but, owing to its rapid disintegration and to the inability of streams on their prevailingly low gradients to transport coarser material, little of it is carried to the lake. No quartz sands, except a few very thin strata in the shales, are known in the area.

The most widespread and conspicuous formation exposed in the area is the Fort Riley limestone, which crops out in the south shore of the reservoir and in adjacent slopes above it (fig. 4). This formation is the key horizon used in the detailed structural mapping of the famous Eldorado oil field, the main producing area of which lies about 7 miles west of the reservoir. Lake Eldorado was built chiefly because salt water from drilling operations had contaminated practically all sources of water for several miles west of Eldorado.

The limestones of the area are more or less porous, which suggests that active circulation of ground water occurs.

Topography and drainage.--The Lake Eldorado drainage basin is a portion of a smooth westward-sloping plain of low relief. Elevations range from 1,300 feet above sea level at the reservoir to about 1,520 feet at the eastern edge of the drainage area, which is marked by a steep eastward-facing escarpment trending generally northward. The steepest slopes in the area are the low bluffs along the south shore of the reservoir, which rise about 8 feet above spillway-crest level. The slope from the top of these bluffs to the upland is about 6 percent. On the north side of the reservoir the slope rising to the upland has been developed chiefly upon shale and has an inclination rarely exceeding 3 percent.

Satchel Creek, the main stream, is intermittent, flowing only during and immediately after rains. It has an average gradient of about 20 feet per mile and flows through a broad, shallow valley whose flood plain is about one-fourth mile wide near the reservoir. The stream follows a moderately meandering course which practically bisects the drainage area. It has no important tributaries, as most of the run-off travels down the smooth slopes directly into the main stream. The stream channel one-half mile above the lake is about 40 feet wide, 8 feet deep, and contains local deposits or bars of both limestone gravel and silt.

Figure 4.—Thin-bedded limestone on south shore of Lake Eldorado.

Figure 5.—Typical small gully on the south slope of Satchel Creek valley near Lake Eldorado.

Soils.--No detailed soil survey has been made in the area, but the soils of this region have been classified by Throckmorton[3] as western residual immature types. They consist chiefly of silt loams and clay loams, prevailingly brown in color, which have been developed by weathering of limestone and shale. Local areas of gravelly soils occur on the Fort Riley limestone. As a whole the soils are relatively thin and well drained. Alluvial phases of gravelly black silt loam have formed in the valley of Satchel Creek near the reservoir.

Erosion conditions.--In some parts of the area sheet erosion is intermittently removing the soil at a rapid rate. Cultivated areas on the valley slopes in sections 10, 11, 14, and 15, T. 25 S., R. 6 E., have already suffered considerable sheet erosion. The greater part of the drainage basin, however, has not suffered serious erosion, chiefly because about 75 percent of the area, including many sections in T. 25 S., R. 7 E., has been maintained in grass pasture land. Some overgrazing in local areas has caused acceleration of sheet erosion on slopes, but the extent of this condition has not been determined.

A few small gullies have formed on the steeper valley slopes between the dam and sections 4 and 5, T. 25 S., R. 7 E. Few of the gullies exceed 250 yards in length, 50 feet in width, and 3 feet in depth. When once started on cultivated or overgrazed slopes they grow rapidly headward, but their downward growth is limited by the resistant limestones and impervious shales beneath the soil (fig. 5).

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[3]Throckmorton, R. I. Kansas soils and soils map. Kansas State Board of Agriculture, 28th Biennial Rept., pp. 91-103, 1933.

Land use.--Approximate figures on land use were obtained by automobile traverse during the survey and are shown in the following tabulation.

Land use in the Lake Eldorado drainage basin in 1937

Use	Proportionate area
	Percent
Cultivated land:	
Wheat	10
Corn and maize	5
Miscellaneous	5
Total	20
Woodland	5
Grazing land	75
Total drainage area	100

Extending nearly one-half mile from each shore of the lake below segment 13 is an area of grassland, much of which has been developed as a municipal park. By maintenance of grass cover nearly all the slopes in this area are fairly well protected from erosion. Considerable sheet erosion is occurring, however, along the slopes near the upper part of the lake, from segment 13 to the head of backwater and beyond. Much of this area is cultivated in wheat, and other areas have been overgrazed. Trees grow almost exclusively along the bottom of the main valley. About 10 stock ponds larger than 1 acre in area are in use on grazing lands of the drainage basin, but their influence on the rate of deposition in Lake Eldorado probably is slight.

Mean annual rainfall: (Records of the United States Weather Bureau at Eldorado):

Period	Inches
1892-1937	31.60
1928-1937	31.18

Draft on reservoir.

The average daily draft on the reservoir is about 200,000 gallons, of which one-half is treated for city use and one-half is pumped untreated for industrial use. The season of maximum water

use is July and August, and the greatest consumption for a 24-hour period has been 1,440,000 gallons. Water from the lake is used by three industries, namely, oil refineries, the Kansas Gas and Electric Company, and the Atchison, Topeka, and Santa Fe Railway.

METHOD OF SURVEY

Water and sediment volumes in Lake Eldorado were determined by the range method of survey.[4] A primary triangulation system of 17 points was established by plane-table triangulation from a carefully measured base line 2,125.7 feet long extending across the dam. The shore line at spillway level was then mapped by plane table and telescopic alidade on a scale of 1 inch to 200 feet. For the measurement of sediment thickness and water depth 22 ranges were established across the reservoir at suitable positions. All range ends and important triangulation points were permanently marked with concrete monuments, 6 inches in diameter and 2 feet long, set flush with ground level. The appropriate survey numbers were stamped on metal plates imbedded in the tops of the monuments.

Four samples of the bottom sediment were taken from various parts of the lake with the 1¾-inch tubular sampler previously described.[5] All samples were obtained in 1½-inch detachable iron pipe nipples 4 inches long. The nipples containing the sediment were removed from the sampler immediately after being withdrawn from the lake bottom and capped with threaded airtight iron covers for shipment to the laboratory.

A capacity curve (fig. 6) was prepared by means of 2-foot contours on the silt surface drawn from sounding data.

SEDIMENT DEPOSITS

Character of Sediment

As shown by analysis (table 2) the principal constituents of the reservoir sediment, in relative order of abundance, are: (1) sand, (2) silt, and (3) clay. Most of the sand is so fine, however,

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[4] Eakin, H. M. Silting of reservoirs. U. S. Dept. Agr. Tech. Bull. 524: 129-135, 1936.

[5] Jones, Victor H. Advance report on the sedimentation survey of Lake Bracken, Galesburg, Ill. U. S. Soil Conserv. Serv., SS-14, p. 7, May 1937. (Mimeographed.)

Figure 6

Spillway Crest Elevation 1300

Elevation (Feet)

1300
1298
96
94
92
90
88
86
84
82
80
78
76
74
72

000 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200

Water Storage (Acre-Feet)

Figure 6

WATER STORAGE CAPACITY

Eldorado Reservoir

Eldorado, Kansas

May 1937

4-13-38 0-2144

that in field identification the sediment in general would be classified as predominantly silt. The proportion of clay decreases upstream from the dam, and the sand fraction is largest near the head, above range R11. Material coarser than medium sand is scarce in the lake deposits, because nearly all the sediment is derived from weathering products of limestone and shale. Most of the lake sediment below segment 11 is loose and incoherent, having undergone little compaction. Above segment 11 most of the deposits have been compacted by drying during periods of low water. During the exceptionally dry summers of 1933 and 1934 the water level stood between 10 and 14 feet below spillway level for several months, but in normal years the stage ranges from 4 to 9 feet below crest.

The location, depth relations, and moisture content of the four sediment samples are listed in table 1.

Table 1.--Bottom sediment samples from Lake Eldorado

Sample No.	Location	Water depth	Silt thickness	Penetration[1]	Relation of moisture to dry weight of sediment
		Feet	Feet	Feet	Percent
38	Range 8, 260 feet from R8L.....	11.1	1.9	1.9	44.5
39	Range 10, 215 feet from R10L.....	12.0	3.6	3.4	68.2
40	Range 11, 568 feet from R11L.....	11.3	4.5	3.9	59.7
41	Range 15, 276 feet from R15L.....	6.0	3.1	3.0	54.6

[1]Depth to which lower end of the sampler penetrated sediment.

On the basis of the moisture determinations and an assumed specific gravity of 2.6 for the sediment, the average dry weight of the reservoir sediment was computed as 66 pounds per cubic foot.

The results of mechanical analyses of the four sediment samples are given in table 2. The analyses were made by the hydrometer method and consequently are only approximate. The sand fraction,

including all material coarser than 0.05 millimeter, consists chiefly of fine and very fine sand.

Table 2.--Mechanical composition of sediment samples from Lake Eldorado

Sample number	Sand >0.05 mm	Silt 0.05 to 0.005 mm	Clay <0.005 mm
	Percent	Percent	Percent
38	60.9	23.9	15.2
39	53.9	20.0	26.1
40	58.4	24.3	17.3
41	57.4	23.7	18.9

The color of the sediment is prevailingly dark yellowish brown but ranges from nearly black in the thickest deposit in segments 8 to 12 to yellowish gray in the shallow water of the ponded channel. Black streaks caused by buried vegetal debris occur at many places within the deposits.

The contact between the lake deposits and the underlying valley materials is sharp and easily identified nearly everywhere. Compact dark-brown silt loams with local gravelly phases underlie the lake deposits over the greater part of the basin. The botryoidal structure,. dark humus zone, and abundant grass roots in the buried soil made it easily identifiable from samples on the silt-measuring apparatus. In the channel areas the silt has been deposited directly upon limestones and shales of the creek bottom.

Distribution of Sediment

The greatest bulk of the reservoir sediment lies in the lower part of the lake, there being 52 acre-feet, or nearly one-half of the total amount, within 0.5 mile of the dam and no sediment whatever in the upper half-mile of backwater. This distribution appears to be due largely to the prevailingly low water level. The average depth of accumulation, however, is fairly uniform over the entire area of deposition, as shown in figure 7.

Only in segments 1 to 7 had appreciable quantities of sediment been deposited outside the submerged channel. The maximum

Figure 7

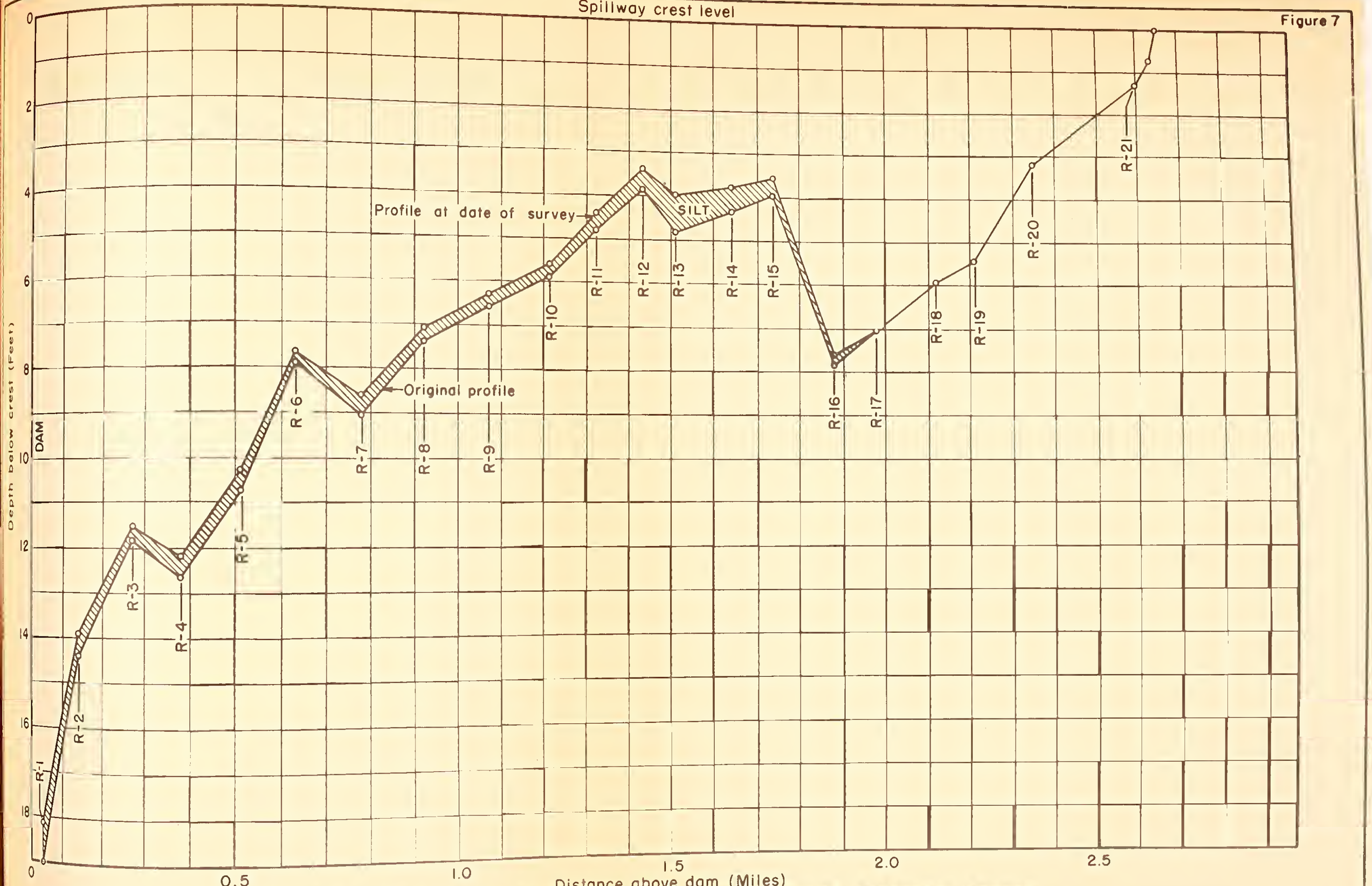

FIGURE 7.– Average-depth profiles, Lake Eldorado, Eldorado, Kansas.

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sediment thickness on range R1 was 1.7 feet, measured in the channel beneath 30 feet of water.[6] On the adjacent valley flat the average thickness was 1.2 feet, but the slopes within 400 feet of shore had practically no sediment.

Measurements on range R3 showed considerably less sediment, only 0.4 foot, on the submerged flat, but a somewhat greater maximum thickness of 1.8 feet in the channel. On range R5 the sediment in the channel was 2.4 feet deep beneath 24.0 feet of water, and deposits on adjacent slopes thinned to 0.5 foot within 300 feet of the channel in both directions. On range R7 the average water depth was about 10 feet, and only insignificant quantities of sediment were found on the valley flat. In the channel, however, a maximum thickness of 2.6 feet was measured beneath 18.6 feet of water. In general it may be stated that little sediment has accumulated in the basin above an elevation of 1,290 feet (10 feet below crest level) except in segments 1 and 2.

Above range R9 very little sediment has been deposited anywhere except in the channel and in a few low places near it. Deposits in segments 11 to 15 are the thickest that have yet accumulated, but they are very limited in area. The channel at range R11 has received 4.5 feet of sediment, but the deposit thins out within 100 feet west and 400 feet east of the channel. Sediment is almost entirely absent above range R15.

The major factors responsible for the distinctive distribution of sediment are readily apparent. During dry seasons, when the lake level falls and remains 5 to 10 feet below crest for periods of weeks, wave action is sufficient to remove practically all accumulated material from the sides of the basin above the 1,290-foot contour, 10 feet below crest. This material is subsequently deposited in deeper parts of the lake. Rains following dry periods produce sufficient inflow to scour the channel and prevent the accumulation of all but very temporary deposits above range R15. When the inflowing currents enter the wider areas of segments 11 to 13 considerable deposition occurs and tends to produce thicker deposits in the channel. The finer fractions of the suspended load are distributed more or less evenly over the main part of the lake bottom. During periods of exceptionally heavy rainfall water flows over the spillway for several days at a time, so that some suspended sediment is carried entirely through the lake.

Origin of Sediment

A brief study of the drainage area indicated that nearly all the reservoir sediment originates from two principal sources, namely,

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[6] All water depths are with reference to spillway crest level.

sheet erosion of soils along the slopes of Satchel Creek valley, and erosion of alluvium along the stream banks above the lake. Sheet erosion has been most severe in sections 1, 11, 12, 14, and 15, T. 25 S., R. 6 E, but in more remote parts of the drainage area it is probably a minor source of sediment. About 10 stock ponds above Lake Eldorado have an estimated aggregate capacity of 50 acre-feet and a total drainage area of 2 square miles. Some of the dams have broken several times, and most of them have been built since construction of the reservoir. The heaviest rains cause free flow of water and sediment over the spillways. The stock ponds have therefore probably trapped only a relatively small amount of sediment and consequently have had only a minor effect on sedimentation in Lake Eldorado.

Wave erosion is a minor factor contributing to sedimentation in Lake Eldorado. In a few places, especially near range ends R6L, R7L, and R8L, wave action has cut low banks in a silty alluvial soil, but the sediment thus derived is estimated to constitute less than 1 percent of the total reservoir deposit. Most of the shore line impinges upon shale and limestone which were originally covered with dark-brown silt loam. The soil has been removed within the range of wave action and subsequent erosion of the bedrock has been relatively slow.

CONCLUSIONS AND RECOMMENDATIONS

The detailed sedimentation survey of Lake Eldorado revealed an average annual accumulation of 14.6 acre-feet of sediment, equivalent to 30.54 cubic feet per acre of drainage area. If the average dry weight of the reservoir sediment is 66 pounds per cubic foot,[7] and that of the soil in the drainage area is 81 pounds per cubic foot,[8] the measured rate of sedimentation indicates that the time required to remove 1 inch of soil from the entire area is about 146 years.[9] This is a relatively low rate compared with many other areas on which similar studies have been made. Land-use conditions have been relatively favorable to low silting rates because

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[7]See footnote 4, page 14.

[8]Based on volume weights given for the surface soil and first horizon of silt loam and clay loam soils (corresponding to the principal soil types in this drainage area) by Middleton, H. E., Slater, C. S., and Byers, H. G. The physical and chemical characteristics of the soils from the erosion experiment stations--second report. U. S. Dept Agr. Tech. Bull. 430:21, 1934.

[9]This figure does not allow for the considerable but indeterminate amount of sediment that has been bypassed through the reservoir.

grazing still remains the chief agricultural pursuit in the drainage area. The city of Eldorado has acquired most of the sloping lands immediately adjacent to the lake and has developed them as a grassed park area.

One prominent source of sediment is State Highway 23, which extends around the north shore of the lake from the dam to range end R13R, but if its ditches were more efficiently protected the damage from this source would be minimized.

The present silting rate is due in large part to sheet erosion on the slopes of Satchel Creek valley between the head of the lake and a point about 3 miles above it. Scientific erosion-control measures in this area alone would probably effect a substantial decrease in the rate of sediment accumulation in Lake Eldorado.

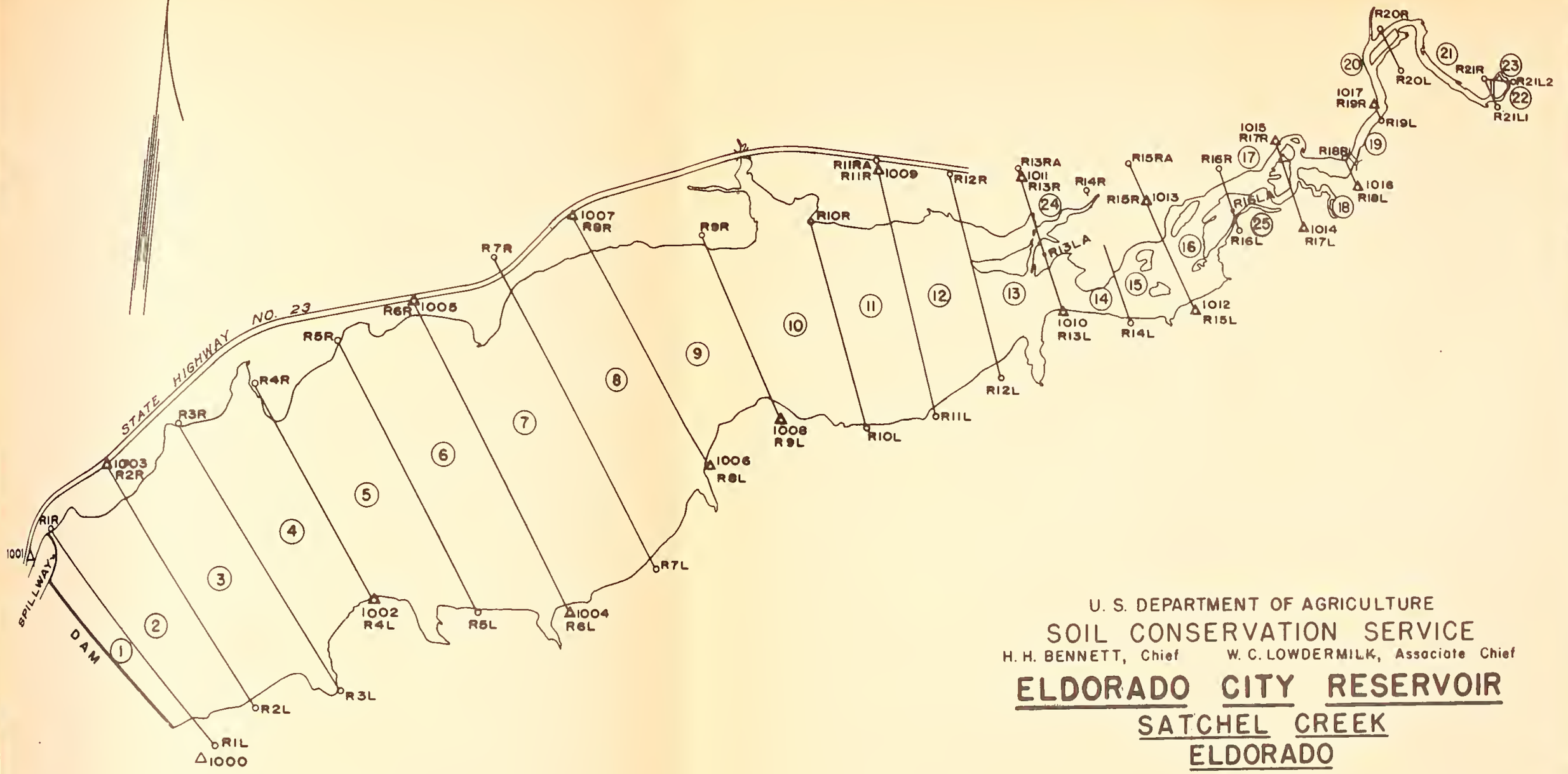
The results of the detailed sedimentation survey of Lake Eldorado are summarized in the following tabulation.

Summary of data on Lake Eldorado, Eldorado, Kans.

	Quantity	Unit
Age[1]	9.0	Years
Watershed area[2]	33.0	Sq. miles
Reservoir:		
Area at spillway stage:		
Original	362	Acres
At date of survey	362	Acres
Storage capacity to spillway level:		
Original	3,213	Acre-feet
At date of survey	3,082	Acre-feet
Capacity per sq. mile of drainage area:[2]		
Original	97.36	Acre-feet
At date of survey	93.39	Acre-feet
Sedimentation:		
Total sediment	131	Acre-feet
Average annual accumulation:		
From entire drainage area	14.6	Acre-feet
Per 100 sq. miles of drainage area[3]	44.9	Acre-feet
Per acre of drainage area:[3]		
By volume	30.54	Cubic feet
By weight[4]	1.01	Tons
Depletion of storage:		
Loss of original capacity:		
Per year	0.45	Percent
To date of survey	4.08	Percent

[1]Storage began in April 1928; average date of survey, April 1957.
[2]Including area of lake.
[3]Excluding area of lake.
[4]Based on an average dry weight of 66 pounds per cubic foot, for four samples, computed from the moisture content (table 1) and an assumed specific gravity of 2.6.

Figure 2



U. S. DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

H. H. BENNETT, Chief W. C. LOWDERMILK, Associate Chief

ELDORADO CITY RESERVOIR

SATCHEL CREEK

ELDORADO

KANSAS

SEDIMENTATION SURVEY OF APRIL 20 TO MAY 8, 1937

G. C. DOBSON, Acting Head, Sedimentation Studies, Division of Research

1000 0 1000 2000 3000

Scale in feet

LEGEND

- 1937 Spillway Crest Line
- R1R—R1L Silt Range
- 1001 △ Triangulation Station
- ① Reservoir Segment Number

Louis M. Seavy, in Charge of Field Survey

0-1905

6-25-37